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ABSTRACT

Levels of achievement and participation in both school mathematics and school science remain unacceptable throughout most of the nation. Addressing these concerns has unique and specific ramifications for small rural schools, particularly with respect to the economic aspects of providing the materials and manipulatives necessary for hands-on instruction and basic laboratory explorations. The purpose of this project/study was to provide opportunities for the improvement of hands-on science and mathematics instruction to the elementary teachers in rural schools of New Mexico. A 6-day summer mathematics and science inservice workshop was provided for 39 rural elementary teachers focusing on minority participation, hands-on activities, and improvement of attitudes toward the teaching of mathematics and science. Among the results were indications of significant improvement in the knowledge of science and mathematics content as measured by a pre- and post-test, which included sections on knowledge, confidence, and anxiety for each of the two disciplines. There were also significant improvements in both confidence measures, as well as significant decreases in both anxiety measures. Additionally, follow-up visits, which were initiated several weeks after the workshop, indicated that the majority of the inservice participants had disseminated their new techniques and materials and were still enthusiastic about the incorporation of a hands-on method of instruction. (36 references) (JJK)

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A HANDS-ON APPROACH TO THE IMPROVEMENT OF RURAL ELEMENTARY TEACHER CONFIDENCE IN SCIENCE AND MATHEMATICS

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ABSTRACT

A summer mathematics and science inservice workshop was provided for thirty-nine elementary teachers from rural small schools throughout the state of New Mexico. The workshop focused on minority participation, hands-on activities, and improvement of attitude towards the teaching of mathematics and science. Pretest-posttest gains revealed significant improvement in knowledge of science and mathematics content, as well as in confidence in the use of hands-on methods to teach mathematics concepts and science process skills. Mathematics anxiety was also significantly reduced. Follow-up visits were made to the participating school districts several weeks later, with survey responses indicating that inservice participants dissseminated their new techniques and materials, and were still enthused with using a hands-on approach in their teaching.

A HANDS-ON APPROACH TO THE IMPROVEMENT OF RURAL ELEMENTARY TEACHER CONFIDENCE IN SCIENCE AND MATHEMATICS [1]

Science and mathematics education continue to be two of the major concerns in U.S. education today. Levels of both achievement and participation in these disciplines are not acceptable (National Science Board Commission on Pre-college Education in Mathematics, Science, and Technology, 1985, p. 15; Educational Testing Service, 1988; National Council of Teachers of Mathematics, 1989, p. 1). Addressing these concerns has certain ramifications that are unique to rural small schools. One problem that is related to the rural small school environment hinges on the understanding that mathematics and science are cumulative, like foreign languages. Students need as many years as possible to interact with mathematical and scientific concepts in the real world (Arons, 1977; National Center for Improving Science Education, 1989, p. 3). This means that all elementary schools, including those in more isolated areas, must begin instruction in mathematics and science in the child's early school years.

Most science and mathematics educators agree that a hands-on, inquiry based approach in elementary school is the most effective means of instruction (Shymansky, Kyle, & Alport, 1983; Copeland, 1984; Suydam, 1984; Gauld, 1988). Experimental investigation is what science is all about. The use of manipulatives in elementary mathematics instruction is advocated to minimize anxiety and to improve conceptual understanding (Taylor & Brooks, 1986; Kennedy & Tipps, 1988, pp. 18-21). A hands-on approach to these disciplines is also advocated by cognitive theorists such as Piaget, Bruner, and Dienes (Heddens & Speer, 1988, pp. 3-7).

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The rural small school situation presents problems for hands-on instruction in that it is materials intensive. This means that the school must have the economic resources to purchase proper equipment. This is often not the case in the rural small school (Howley, 1988). Hands-on materials also require up-to-date scientific knowledge. Rural teachers often complain these are not available due to their professional isolation (Jinks & Lord, 1990). As a result, many teachers develop a negative attitude and do not spend enough time teaching science (National Science Foundation, 1980; Weiss, 1987).

Improvement of math instruction among elementary teachers also involves attitude improvement. Unfortunately, mathematics anxiety is prevalent among elementary teachers (Buhlman & Young, 1982). Limited participation in mathematics courses at the secondary level can be blamed at least in part on lack of confidence due to mathematics anxiety that has its roots in the elementary school experience (Fennema & Sherman, 1976; Frary & Ling, 1983; Reyes, 1984). Minorities are particularly susceptible to both mathematics anxiety and reduced participation in mathematics and science (Amodeo & Emslie, 1985; Burton, 1984; Valverde, 1984).

Although rural schools have financial constraints (Howley, 1988), their lower pupil-teacher ratio and their autonomy are often powerful advantages after teachers once become involved and committed to a new program. While urban teachers are often forced to try new programs that come and go, the momentum for improvement in rural small schools is frequently initiated and perpetuated by teachers rather than curriculum coordinators or principals (Killian, 1988). These factors can make summer inservice workshops particularly advantageous to rural teachers, and increase the likelihood of the sharing of new ideas with their peers. Research does support the assumption that outstanding teachers evolve over a period of time to become more "complete" teachers, with workshops and inservices being one instrumental part of their professional growth (Kierstead, 1985).

An appropriate workshop for elementary teachers is one that gives training in both the construction of hands-on equipment with inexpensive, local, everyday materials, and the proper applications of these materials to effective instruction. Workshops have proven to be effective in not only the improvement of lab equipment usage, but also the improvement of teacher attitudes and confidence toward teaching with such materials (Bitner-Corvin, 1986; Fraser-Abder, 1984). Improved attitude seems to go hand in hand with the development of confidence from gaining competency in the use of new techniques, which can often take place within a fairly brief time period (Sparks, 1988; Spooner, Szabo, & Simpson, 1982). All day workshops of a week or so in length have proven to be effective in promoting teachers to apply acquired knowledge on a continued basis (NSF, 1988; Greabell, 1990).

The purpose of the project described in this study was to provide opportunities for the improvement of hands-on science and mathematics instruction to the elementary teachers in the rural schools of New Mexico. Most of the rural schools in New Mexico have large concentrations of Hispanic or Native American students. These students are often in need even more so than the non-minority students in mathematics and science education due to their characteristic underrepresentation in such courses and consequently mathematics, science, and technology careers (Chipman & Thomas, 1984; Thomas, 1986). Within the next few decades the predominant portion of our labor force will cease to be white males (National Research Council [NRC], 1989, pp. 20-22). Since an increasingly larger percentage of new careers are science and technology related, we must get minorities and females involved in order to make the most efficient use of human resources. Without such participation, our country will not be competitive in the world market, which will result in a reduced standard of living (James & Kurtz, 1985; NRC, 1989, pp. 4-9).

The summer inservice workshop in this project focused on three specific goal areas:

1. Improvement of instructional skills that impart science knowledge and concepts to children through the use of hands-on teacher-made equipment.
2. Improvement of teacher attitude towards the teaching of science and mathematics through an increase in confidence and a reduction in mathematics anxiety.
3. Participation by minority teachers in order to improve their success as role models in science and mathematics for minority students.

METHOD

Workshop Format and Content

A six-day summer workshop was designed for elementary teachers to enroll in pairs, one pair from each participating rural school district. At least one of the two teachers in each pair was required to be a minority. This was to insure that minority participation would be at least fifty percent. Ethnic make-up of the participants (N=39) was 17 Anglos, 16 Hispanics, 2 American Indians, 1 Black, and 3 others (of which one was Hawaiian). The project provided room and board for all participants at New Mexico State University, as well as tuition and fees so that each participant received two hours of graduate credit for satisfactory completion of the workshop. Each day the schedule included both the construction of teacher-made manipulatives and demonstration and practice in their appropriate uses for instruction.

Selection of the specific materials and activities included in the workshop were made according to the following four criteria: (a) ability of the teacher to construct the manipulative without undue inconvenience, (b) usefulness in the classroom for teaching accepted state mathematics and science competencies, science

process skills, and NCTM standards, (c) low expense and availability of materials, and (d) student appeal. In preparation for the workshop, a detailed manual was created, which included eleven mathematics manipulatives and ten hands-on science activities, each with instructions on how teachers can construct them from readily available materials, and then several hands-on activities for which the manipulatives can be used (Hadfield, 1989). Many of the activities included in the manual were suggested by pre-existing sources such as journal articles or commercial kits. In such cases the sources were listed to give credit where due, and also in hopes that the teacher might explore further uses of the same materials.

The eleven math manipulatives were as follows: number blocks, attribute shapes, chip trading, polyhedron models, decimal squares, circular geoboards, arithmetic tiles, fraction disks, integer abacus, probability spinners, and tangrams. The activities associated with these manipulatives included the following competency areas: prenumeration, counting, place value, whole number operations, addition and subtraction algorithms, multiplication and division algorithms, fractions, decimals, percents, number theory, geometry, probability, integers, and critical thinking.

The ten science activities were as follows: circuit boards, chromatography, fingerprinting, balloon races, ball bounce, Bernoulli's principle, flying gyroscopes, inclined plane acceleration, pendulums, and Rutherford's box. The competencies associated with these activities included the following areas: conductivity and circuits, chromatography, classification of data, volume and displacement, gravity, velocity, air pressure and motion, flight, mass, pendulums and periodicity, and atomic structure. Most of the science process skills were used in several experiments.

Materials primarily included poster board, wood, nails, wire, paint, string, glue, straws, etc. After 60 to 90 minutes of construction time for each of the

manipulatives, up to two hours was spent in demonstration and teaching practice with the finished products. At the close of the workshop, each teacher was furnished plastic crates to transport all of their teacher-made manipulatives. They were asked to lead inservices for their district, and to share their materials. They were informed that follow-up visits to their district would be made, in order to find out if they had disseminated the knowledge and materials, as well as to collect information on how receptive the students and the teachers were to the various materials and ideas.

Evaluation

A pretest was given on the opening day of the workshop, and was then administered again as a posttest on the last afternoon of the week-long workshop. The test had six sections of questions. The three mathematics sections included knowledge of math manipulative use, mathematics confidence, and mathematics attitude (anxiety). The math manipulative knowledge section consisted of twenty-seven multiple choice items which were directed specifically toward the manipulatives used in the workshop. The mathematics confidence section consisted of seventeen questions on a Likert-type scale that questioned how confident the teachers were with the use of certain manipulatives and the teaching of specific competencies through their use. The mathematics attitude scale was adapted from Ferguson's Phobus Inventory (Ferguson, 1986), and also consisted of a Likert-type scale to be applied to thirty questions that rated subjects on their discomfort with numerical tasks, mathematics tests, and mathematical abstraction tasks.

The three sections of the test which contained science questions included science knowledge, science teaching confidence, and science teaching attitude (science anxiety). The hands-on science knowledge section consisted of twenty

multiple choice items which were content oriented, but were directed specifically toward the lab activities used in the workshop. The science teaching confidence section consisted of ten items on a Likert-type scale that questioned how confident the teachers were with the use of certain hands-on materials and the teaching of specific competencies through their use. The science attitude scale also consisted of a Likert-type scale applied to twenty-one questions that rated subjects on their discomfort with science and science teaching tasks. Demographic data were also collected, including number of years of teaching experience, ethnic group, grade level taught, school size, number of graduate courses, and age. At the conclusion of the workshop, photos of the participants were taken, and news releases were sent to their school districts. Local newspapers then circulated articles describing the workshop, complete with photos of their representatives.

Follow-up visits were made to each of the twenty-one school districts. The original participants were interviewed, and were also instructed to fill out an anonymous questionnaire concerning their views of the project. Some of the questions inquired as to which and how many of the materials and activities they had used, which were most effective, what the student response was like, and if they had increased their total time per week teaching science or mathematics. Also it was asked if they had done an inservice or shared materials with their peers, and if they felt that their confidence in teaching science or mathematics had improved.

Data Analysis

Paired t-tests were used to compare pretest and posttest scores in all six areas: math manipulative knowledge, math confidence, math attitude, science knowledge, science teaching confidence, and science teaching attitude. Comparisons were also made with a series of one-way ANOVA's for possible differences in each of these six variables at the various levels of six demographic variables. Results of

the follow-up interviews and questionnaires were also quantified to give an overall picture of the project outcome.

RESULTS

Table 1 reveals that pretest-posttest differences in five of the six areas were significant at the $p < .0001$ level. It was not surprising that the participants showed significant gains in mathematics manipulative knowledge, mathematics confidence, science knowledge, and science teaching confidence, since the workshop itself was directed so specifically toward these areas. The significant reduction in mathematics anxiety was also pleasing, even though it was not expected to occur. Perhaps the increase in confidence in the teachers' ability to effectively teach math with the manipulatives led directly to their reduction in anxiety and improvement of attitude.

Table 1
Degree of Improvement in Six Test Subscales

		Pretest	Posttest	Difference	*t*	$p < \|t\|$
Math Knowledge	*M*	4.41	22.21	17.79	33.65	.0001
	SD	2.92	2.86			
Math Confidence	*M*	46.18	65.31	19.13	5.33	.0001
	SD	13.25	18.70			
Math Anxiety	*M*	92.79	74.05	-18.74	-4.27	.0001
	SD	29.55	24.95			
Science Knowledge	*M*	7.41	16.60	9.18	18.53	.0001
	SD	2.88	1.97			
Science Confidence	*M*	26.95	39.77	12.82	7.47	.0001
	SD	8.08	8.74			
Science Anxiety	*M*	53.46	51.79	-1.67	-0.51	.6137
	SD	17.61	18.49			

There was no significant improvement in science teaching attitude (science anxiety). It had been hoped that the confidence gained in the teachers' ability to effectively teach science with hands-on materials would lead directly to an improvement. The mean score of 53.46 out of a possible 105 points on the pretest indicates a fairly positive attitude towards science at the outset, perhaps making it more difficult to show significant improvement. The fact that the workshop was voluntary should also imply that teachers who thoroughly detested science would not attend. Another explanation is that the science attitude scale may not have been a valid instrument. It was constructed specifically for this project, with no previous norming, and therefore its validity and reliability are suspect. The items on the instrument may refer to teaching practices too much, like "I postpone science lessons". It would be hard to expect a different answer on these items at the end of the workshop, before the teachers actually go back to their classrooms and have a chance to establish whether or not they have changed their "routine" towards science. Follow-up visits to the schools did find substantial improvement in science teaching, this suggests that the science teaching attitude section of the instrument was not valid.

The series of one-way ANOVA tests found no significant differences in the levels of teacher age, experience, years of higher education, grade level taught, or ethnicity with respect to any of the three dependent variables of mathematics manipulative knowledge, mathematics confidence, or mathematics attitude. The only significant findings were that with respect to both mathematics anxiety ($F = 8.86, df = 1/37, p < .0061$) and science confidence ($F = 8.85, df = 1/37, p < .0085$), school size was a factor . Teachers from schools of less than two hundred and fifty students ($n = 16, m = 50.39$) had significantly higher levels of mathematics anxiety than did teachers from schools with two hundred and fifty or more students ($n = 23, m = 40.13$). Also, teachers from schools of less than two hundred and fifty

students (n =16, m = 23.88) had significantly lower levels of science teaching confidence than did teachers from schools with two hundred and fifty or more students (n = 23, m = 29.09). This reflects a lack of confidence in both mathematics and science in general, which is not surprising if one accepts the previously mentioned premise that professional isolation in the smaller schools presents certain problems. The follow-up visits to the schools resulted in overwhelming compliments on the experiences during attendance of the workshop, and the usefulness of its content and materials. Many teachers suggested planning another similar workshop for themselves and others who missed the first opportunity. Although only 60% conducted actual inservices, the information was still disseminated to peers at least to some degree in all cases. The popularity of the various materials is summarized in Table 2.

The popularity of number blocks was not surprising, in that they were a combination of Diene's blocks and Cuisenaire rods, which are quite useful for teaching counting, place value, and basic whole number operations. Chip trading, attribute blocks, and arithmetic tiles were also rated highly, probably for similar reasons. Tangrams were a surprise, because we felt that they were probably already in heavy use by most teachers. Apparently not. Polyhedron models appeared to be the most fun during the workshop phase, but perhaps they were too much trouble to assemble, or not pertinent to the competencies. Decimal squares were rated disappointingly low. They are effective for teaching decimals and percents, and students seriously need manipulatives in these areas. Perhaps our workshop presentation of this manipulative needs improvement.

Table 2
Summary of Mathematics and Science Activity Follow-Up Usage

ACTIVITY	NUMBER	AVERAGE	WEIGHTED SCORE
Mathematics			
Number Blocks	15	4.8	72
Tangrams	13	5.5	72
Chip Trading	14	4.9	68
Attribute Shapes	8	5.9	47
Arithmetic Tiles	10	3.8	38
Circular Geoboard	7	5.1	36
Fraction Disks	6	5.3	32
Polyhedron Models	5	4.4	22
Decimal Squares	3	4.7	14
Integer Abacus	2	3.5	7
Probability Spinners	0	0.0	0
Science			
Circuit Boards	13	4.9	64
Inclined Plane	14	4.4	61
Pendulums	8	5.0	40
Balloon Races	8	4.3	34
Chromatography	8	4.1	33
Rutherford's Box	6	5.3	32
Fingerprinting	5	3.8	19
Flying Gyroscopes	3	5.0	15
Ball Bounce	3	5.0	15
Bernoulli's Principle	3	5.0	15

Note: Number indicates the total number of times each activity was reported as one of the six most used. Average is the mean of all responses, with 6 as the highest possible rating, and 1 as the lowest. Weighted Score is the product of Number x Average.

In the science area, the popularity of the circuit board and inclined plane activities was not surprising in that they both drew a lot of excitement during the workshop. The circuit board activity promoted both creativity and competition. It allowed one person to design a circuit and then their challenger to run a series of tests to determine what the secret circuit design was. The inclined plane activity

also had a competitive aspect when students released toy cars to roll down the plane and then measured their velocity and total distance traveled.

The pendulum activity was rated higher than expected. Due to its lack of fancy equipment and the more advance level of required mathematics in the graphing portion, it was a surprise to see it so well received. Apparently, though, it created an effective learning situation. The Bernoulli's principle experiment was probably rated low because it was a little over the heads of the elementary students. The flying gyroscopes experiment was quite fun in the workshop, but teachers commented that it was a lot of activity without much conceptual foundation. A lot of fun, but no significant learning. Generally, though, most of the activities were effectively used in the elementary classroom.

CONCLUSIONS AND DISCUSSION

The most important implication of this project is that teachers can benefit from a workshop of limited time length. In light of the significant reduction in mathematics anxiety scores and the improvement in so many other areas, it appears that inservices and workshops could be one key to counteracting the professional isolation of teachers in small rural schools. The participants showed interest and involvement, improved in both content knowledge and techniques with hands-on materials, and they have a tendency to use and share the materials and ideas in their own classrooms. Many science and math educators as well as school administrators assume that elementary teachers are well versed in the use of manipulatives and hands-on activities because of college methods courses. We found that this is not the case. Teachers had not used many mathematics manipulatives or hands-on science activities, and were not very familiar with them. It is encouraging, that they were receptive to the new materials and ideas, and were excited to share their own creations with peers and students. It is also important that their interest was

without regard to their age, grade level, or experience. More workshops of this type are recommended, as they seem to be a viable part of the solution to enhancing our current elementary mathematics and science education programs, particularly in small rural schools.

The activities during the inservice apparently resulted in more effective science and mathematics teaching in the following ways:

1. Sparked creativity in teachers.
2. Made more hands-on materials available to them.
3. Allowed teachers and students to see alternative applications of common materials.
4. Helped teachers with ideas on how to teach science on a limited budget.
5. Improved teacher attitudes towards the teaching of science and math.
6. Improved teacher knowledge and skills in the teaching of science and math.

The potential for generalizing the project findings to similar situations across the country is self-evident. Similar detailed inservice manuals could be developed by other districts.

In summary, students benefit by having hands-on experiences in mathematics and science. These experiences can be partially provided by common everyday materials with which the students are familiar, rather than expensive equipment. Teachers benefit by having a deeper understanding of the equipment and how it works; having the ability to instruct effectively with it; and the ability to design new and interesting materials. Administrators benefit from the low cost hands-on materials. The college or university implementing the program benefits from having built the seed that blossoms into a low cost version of effective science and mathematics education, and a network of partnership with rural districts throughout the state. The state benefits by having a vehicle to implement and sustain their recommended competencies in mathematics and science education.

REFERENCES

Amodeo, L.B. & Emslie, J.R. (1985). *Effects of a mathematics intervention program on the computational skills and attitudes of preservice elementary and secondary teachers.* Portales, NM: Eastern New Mexico University. (ERIC Document Reproduction Service No. ED 270 247)

Arons, A.B. (1977). Development of the capacity for abstract logical reasoning. *Journal of College Science Teaching, 6* (4), 248-49.

Buhlman, B.J. & Young, D.M. (1982). On the transmission of mathematics anxiety. *Arithmetic Teacher, 30* (3), 55-6.

Bitner-Corvin, B.L. (1986). *Yearlong inservice science workshop: Its effect on the attitudes of teachers K-7.* Springfield, MO: Southwest Missouri State University. (ERIC Document Reproduction Service No. ED 295 797)

Burton, G.M. (1984). Revealing images. *School Science and Mathematics, 84* (3), 199-207.

Chipman, S.R. & Thomas, V. (1984). *The Participation of Women and Minorities in Mathematical, Scientific, and Technical Fields.* Washington, DC: Institute for Urban Affairs and Research, Howard University.

Copeland, R.W. (1984). *How children learn mathematics: Teaching implications of Piaget's research.* New York: MacMillan.

Educational Testing Service. (1988). *The science report card: Elements of risk and recovery.* Princeton, NJ: Author.

Fennema, E. & Sherman, J. (1976). Fennema-Sherman Mathematics Attitudes Scale. *Psychological Documents* (Ms. No. 1225)

Ferguson, R.D. (1986). Abstraction anxiety: A factor of mathematics anxiety. *Journal for Research in Mathematics Education, 17* (2), 145-50.

Frary, R.B. & Ling, J.L. (1983). A factor-analytic study of mathematics anxiety. *Educational and Psychological Measurement, 43* (1), 985-93.

Fraser-Abder, P. (1984). *The effect of participation in an activity oriented science curriculum development workshop on the attitude of elementary teachers in Trinidad and Tobago.* St. Augustine, Trinidad, West Indies: University of the West Indies, School of Education. (ERIC Document Reproduction Service No. ED 244 779)

Gauld, C.F. (1988). The cognitive context of pupils' alternative frameworks. *International Journal of Science Education, 10* (3), 267-74.

Greabell, L.C. & Phillips, E.R. (1990). A summer mathematics institute for elementary teachers: Development, implementation, and follow-up. *School Science and Mathematics, 90* (2), 134-41.

Heddens, J.W. & Speer, W.R. (1988). *Today's Mathematics* (6th ed.). New York: Macmillan.

Hadfield, O.D. (1989). *A manual for teacher-made science activities.* Las Cruces, NM: New Mexico Center for Rural Education, New Mexico State University.

Howley, C.B. (1988). Economic support for education in rural school districts. *ERIC Digest.* Charleston, WV: ERIC Clearinghouse on Rural Education and Small Schools. (ERIC Document Reproduction Service No. ED 308 059)

James, R.K. & Kurtz, V.R. (Eds.). (1985). *Science and mathematics education for the year 2000 and beyond: Topic for teachers series number 4.* Bowling Green, OH: School Science and Mathematics Association.

Jinks, J. & Lord, R. (1990). The Better Elementary Science Teaching Project: Overcoming the rural teacher's professional and academic isolation. *School Science and Mathematics, 90* (2), 125-33.

Kennedy, L.M. & Tipps, S. (1988). *Guiding Children's Learning of Mathematics,* (5th ed.). Belmont, CA: Wadsworth.

Kierstead, J. (1985). Supporting the evolution of effective teachers. *Teacher Education Quarterly, 12* (2), 32-41.

Killian, J.E. & Byrd, D.M. (1988). *Teachers' perspectives on what promotes instructional improvement in rural schools.* Carbondale, IL: Southern Illinois University. (ERIC Document Reproduction Service No. ED 301 402)

National Center for Improving Science Education. (1989). *Getting started in science. A blueprint for elementary school science education.* Washington, DC: Office of Educational Research and Improvement.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics* (ISBN 0-87353-273-2). Reston, VA: Author.

National Research Council. (1989). *Everybody counts: A report to the nation on the future of mathematics education* (ISBN 0-309-03977-0). Washington, DC: National Academy of Science.

National Science Foundation. (1980). *Science education databook.* Washington, DC: Author.

National Science Foundation. (1988). *The middle grades mathematics project. The challenge: Good mathematics taught well.* Final Report to the National Science Foundation. East Lansing, MI: Michigan State University, Department of Mathematics. (ERIC Document Reproduction Service No. ED 295 793)

Reyes, L.H. (1984). Affective variables and mathematics education. *Elementary School Journal, 84* (5), 558-81.

Shymansky, J.A., Kyle, W.C., & Alport, J.N. (1983). The effects of new science curricula on student performance. *Journal of Research in Science Teaching, 20* (5), 387-404.

Sparks, G.M. (1988). Teachers' attitudes toward change and subsequent improvements in classroom teaching. *Journal of Educational Psychology, 80* (1), 111-17.

Spooner, W.E., Szabo, S.E., & Simpson, R.D. (1982). The influence of a five-day teacher workshop on attitudes of elementary school teachers toward science and science teaching, Part II. *School Science and Mathematics, 82* (8), 629-36.

Suydam, M.N. (1984). Research report: Manipulative materials. *Arithmetic Teacher, 31* (5), 23-35.

Taylor, L. & Brooks, K. (1986). Building math confidence by overcoming math anxiety. From theory to practice. *Adult Literacy and Basic Education, 10* (1). (ERIC Document Reproduction Service No. ED 272 741)

Thomas, G.E. (1986). Cultivating the interest of women and minorities in high school mathematics and science. *Science Education, 70* (1), 31-43.

Valverde, L.A. (1984). Underachievement and underrepresentation of Hispanics in mathematics and mathematics-related careers. *Journal for Research in Mathematics Education, 15* (2), 123-33.

Weiss, I.R. (1987). *Report of the 1985-86 national survey of science and mathematics education*. Research Triangle Park, NC: Research Triangle Institute.